IDA

Mission Stream Analysis – Δ Analytic Model

James A. Forrest, Lead
James R. Dominy
Marion L. Williams
Patricia F. Bronson

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Executive Summary

This paper describes two analytic tools for enhancing the foundational analysis and the mission effectiveness outcome on major defense acquisition programs. The first tool is Mission Stream Analysis, which aids in decomposing the mission and system capabilities/requirements into system technical performance, operator workload requirements, and metrics that contribute to demonstrating mission effectiveness. The second tool is the Δ (Delta) Analytic Model, which provides an approach for identifying disparate interpretations of the systems requirements and metrics in the analytic foundation so that the differences can be eliminated.

Mission Stream Analysis is conducted on a system for a specific mission scenario. It decomposes a mission scenario into a series of offensive and defensive kill-chains, survivability spectra, and other mission tasks. With each task is associated the capabilities and mission systems needed to perform the task. The missions, so modeled, provide a framework for the communities that participate in establishing the requirements, metrics, and tests that will demonstrate the system can effectively complete the missions for which it is intended. We believe the effectiveness measures that are output from the mission stream analyses are as important to a program's success as the Key Performance Parameters.

The Δ Analytic Model seeks to eliminate disparate interpretations of the systems requirements and metrics, by identifying differences, in the Analytic Foundation of the program. The Δ Analytic Model is the "domain-centric" environment in which communities reach <u>down</u> to the Analytic Foundation for key elements of information, regardless of the time phasing of the program. For the Δ Analytic Model to work, the Analytic Foundation must be transparent and readily available to all communities, and all communities must recognize the Analytic Foundation as the authoritative source of information. We envision a model that is not unlike Wikipedia with permissions.

Contents

1.   Introduction

Weapon system program development problems, as evidenced by significant cost increases and schedule delays, highlight the need to improve both discipline and oversight in the Department of Defense (DoD) acquisition process. Senator John McCain best articulated these problems in his comments on February 4, 2013:[1]

> There are far too many examples where the Department begins a major program without knowing what it really wants or how these requirements should translate into technical specifications that are designed to generate the combat capability it really needs. Also, all too many times, there is no traceability between these specifications through a test regime that is sufficient to ensure that the system the Department is procuring is operationally effective, suitable and survivable before entering operational testing or early production.

To address these issues, this paper proposes a methodology based on well-defined "system" and "mission" requirements that (1) enables the development and execution of an efficient and effective design and validation process, and (2) provides confidence that the performance of a system is understood and developed in the mission context. The proposed methodology includes:

- A "Δ Analytic Model" that provides for better cross-domain (requirements, systems engineering, and test and evaluation) collaboration and analysis. The model helps reduce definitional conflicts and aligns development expectations across domains; this model is a companion to "Mission Stream Analysis."

- "Mission Stream Analysis" is based on the concept that weapon systems are designed around the synergy between man (operator's capability) and machine (system's technical performance) to effectively accomplish a mission.[2] In essence, mission stream analysis is a tool for defining, developing, and evaluating a weapon system's capability to obtain, integrate, analyze, share, and act on information within the operator's decision cycle in order to effectively

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[1] "Floor Statement by Senator McCain on the Defense Department's 'Culture of Inefficiency' and Senator Hagel's Nomination," John McCain, U.S. Senator, Arizona, http://www.mccain.senate.gov/public/index.cfm/floor-statements?ID=a7256332-b509-07dd-5300-18230cfbfe04.

[2] "The PM shall apply human systems integration to optimize total system performance (hardware, software, and human), operational effectiveness, and suitability, survivability, safety, and affordability." DoD Directive (DoDD) 5000.01, *The Defense Acquisition System* (Washington, DC: Under Secretary of Defense (Acquisition, Technology and Logistics), May 12, 2003). Certified current as of November 20, 2007.

conduct missions and survive. It was developed to assist practitioners in quantifying weapon system maturity; characterizing mission capability; and projecting operational effectiveness, suitability, and survivability.

The proposed "Δ Analytic Model" and "Mission Stream Analysis" are cross-domain tools that could enhance the foundational analysis of a program; aid in devolving the envisioned mission and system capability requirements into a system's technical performance and operator workload requirements; and help minimize the "delta" between domains across the system's lifecycle, from program definition through design, development, and test.

2. Mission Stream Analysis

Mission stream analysis considers all mission-related tasks a weapon system is expected to accomplish during an end-to-end mission, including execution of all offensive kill-chain functions to engage an enemy threat and execution of all defensive capabilities to survive an enemy threat. The term "mission stream analysis" was coined by IDA's Cost Analysis and Research Division, and is not in general use in the DoD acquisition community; however, mission-based testing and kill chain analysis is used by the Navy Operational Test and Evaluation Force[3] and other Service test organizations. Mission stream analysis is intended to assist Systems Engineers (SEs) and Test and Evaluation (T&E) practitioners in precisely characterizing observed system performance (i.e., test results) in terms of mission capabilities that relate to effectiveness. In practice, mission stream analysis

- Provides a high-level depiction of mission sets and the associated tasks required to accomplish operationally realistic missions;[4]

- Provides developers with a basis for devolving operational concepts and missions into sets of specific tasks, performance attributes, and technical performance and mission effectiveness measures;[5]

- Provides a methodology to explore a system's mission tasks and objectives to identify inconsistencies and gaps between user requirements and the performance parameters used to design, develop, and test and evaluate the system; and

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[3] COMOPTEVFOR Instruction 3980.2C, Code 01A (Norfolk, VA: Department of the Navy, Commander Operational Test and Evaluation Force, April 14, 2014).

[4] The authors believe that the Joint Capabilities Integration and Development System (JCIDS) Manual, 2012, provides a foundation for mission stream analysis and associated success criteria; the Manual states "The CBA must also develop criteria for adequate mission performance. Quantitative criteria for mission success must be established to support the assessment of the materiel reliability characteristics of potential materiel solutions. In most cases, these criteria will not be simple pass-fail standards, but instead will represent a continuum of values."

[5] The DoD Architectural Framework (DoDAF) Version 2.02 provides insight into tasks, activities, and data exchanges, but does not provide the performance and effectiveness measures; more specifically, DODAF states "DoDAF-described Models in the Operational Viewpoint describe the tasks and activities, operational elements, and resource flow exchanges required to conduct operations. A pure operational model is materiel independent…it may be necessary to include some high-level system architectural data to augment information onto the operational models." http://dodcio.defense.gov /Portals/0/Documents/DODAF/DoDAF_v2-02_web.pdf.

- Provides an analytic framework that links major development and test phases.

The Joint Staff's Capabilities-Based Assessment[6] is a primary source of information to support the development of the proposed system's mission streams, since it

> begins by identifying the mission or military problem to be assessed, the concepts to be examined, the timeframe in which the problem is being assessed, and the scope of the assessment. A CBA determines the relevant concepts, CONOPS [Concept of Operations], and objectives, and lists the related effects to be achieved.

Figure 1 depicts a mission stream for a fighter aircraft as a series of mission tasks, from mission planning through assessing mission outcome. In this example, the fighter's offensive kill-chain functions (find, fix, track, target, and engage the enemy threat) is a central concept. The figure also includes the threat fighter's defensive capabilities to deny, defeat, and survive the offensive kill chain associated with the engagement. End-to-end missions may involve execution of many tasks, multiple offensive kill chains, and deny/defeat/ survive multiple threat offensive kill chains.
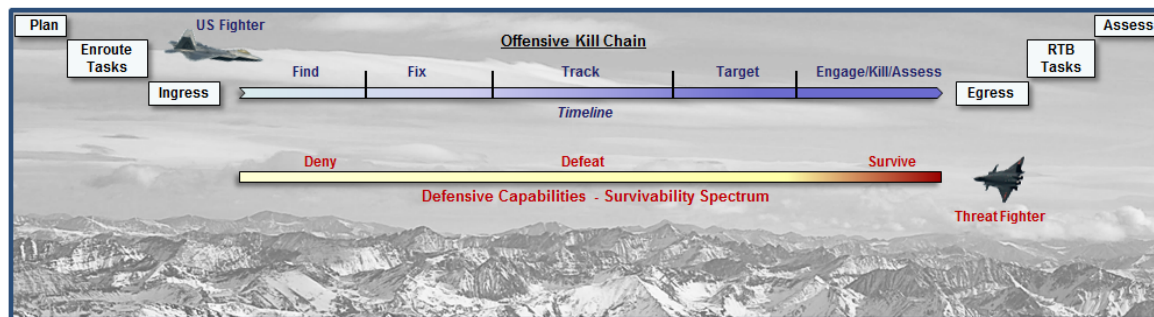

Figure 1. Mission Stream Analysis

In general terms, mission effectiveness requires successful execution of system functions (e.g., completing critical mission tasks and all segments of the offensive kill chain, such as engaging threat fighters, or surviving a threats-offensive kill chain). Success, in turn, depends on the technical capabilities of sub-systems and the operators' ability to perform their roles within the mission timelines.

A model of a notional mission stream associated with a fighter/missile offensive engagement against a threat fighter is shown in Figure 2. In this example, a US fighter is engaging an enemy threat fighter with a long range air-to-air missile. The US fighter's offensive kill chain starts with the pre-missile launch activities, which lead to the launch of the missile (engage function), followed by the missile offensive kill chain that culminates in a kill of the threat fighter. In this example, the objective of the threat fighter

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6   *The Joint Capabilities Integration and Development System (JCIDS) Manual*, 2012.

is to use its defensive capabilities to deny the US fighter engagement, or, if the missile is launched, to defeat the missile and survive.
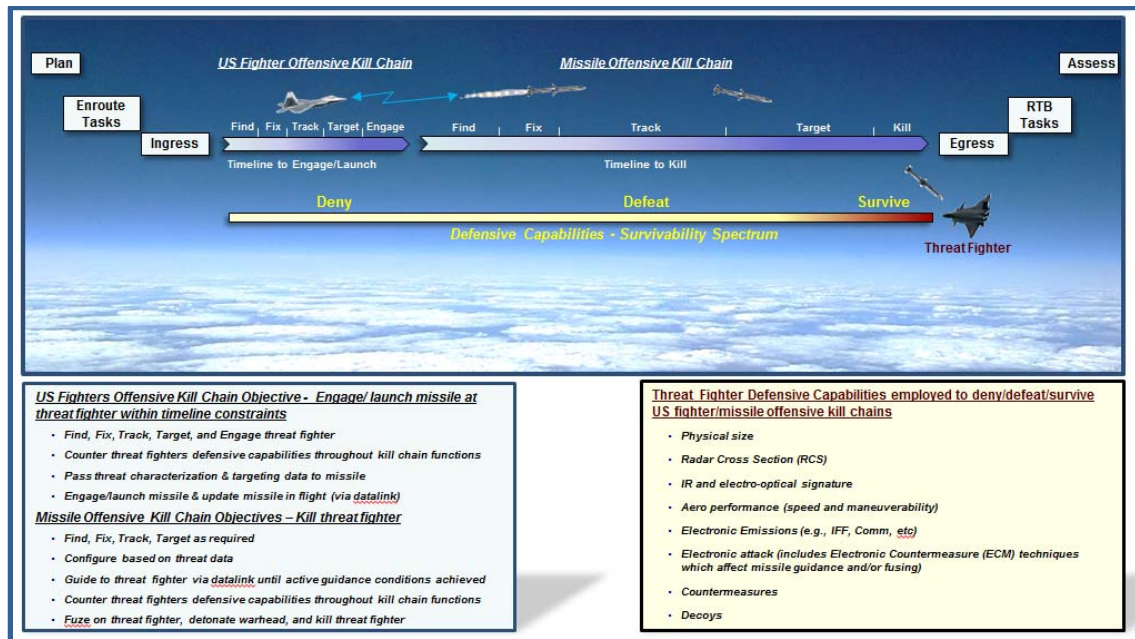

Figure 2. Notional Fighter/Missile Offensive Engagement

The US fighter's air-to-air mission stream starts with mission planning and continues with ground operations, take-off, enroute tasks (e.g., navigation and re-fueling), and ingress into the engagement area.

A more detailed view and objectives of the US fighter/missile engagement's offensive kill chains that compete with the threat fighter's defensive capabilities is shown in Figure 3.[7]

Figure 3. Notional US Fighter/Missile Offensive Kill Chains vs. Threat Fighter Defensive Capabilities

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[7]   Notional for illustrative purposes to help frame the concept.

- US Fighters Offensive Kill Chain Objective – Engage/launch missile at threat fighter within timeline constraints

  – Find, fix, track, target, and engage threat fighter

  – Counter threat fighter's defensive capabilities throughout the kill chain functions

  – Pass threat characterization and targeting data to missile

  – Engage/launch missile and update missile in flight (via datalink)

- Missile Offensive Kill Chain Objective – Kill threat fighter

  – Find, fix, track target as required

  – Configure based on threat fighter data

  – Guide to threat fighter via datalink until active guidance conditions achieved

  – Counter threat fighter's defensive capabilities throughout the kill chain functions

  – Fuse on threat fighter, detonate warhead, and kill threat fighter

- Threat Fighter's Defensive Capabilities – Employ across the survivability spectrum, to deny/defeat/survive the US fighter/missile offensive kill chains. These defensive capabilities include:

  – Physical size

  – Radar Cross Section (RCS)

  – Infrared (IR) and electro-optical signature

  – Aero performance (speed and maneuverability)

  – Electronic emissions (e.g., Identification, Friend or Foe (IFF) and Communications)

  – Electronic attack (includes Electronic Countermeasure (ECM) techniques, which affect missile guidance and/or fuzing)

  – Countermeasures

  – Decoys

In this notional example, the US fighter's air-to-air mission stream ends with egress from the engagement area, numerous tasks on return to base (RTB) (e.g., navigation and re-fueling), landing, and assessment and debrief.

The next step in mission stream analysis is to align the US fighter/missile capabilities with the engagement sequencing across the kill chains (Figure 4). The

engagement sequence includes the US fighter pre-launch–launch phase followed by a three phase post-missile launch sequence: mid-course (semi-active), mid-course (active), and end game. In this case, the model links the mid-course (semi-active) phases of the engagement sequence to both the fighter and missile capabilities using a datalink for guidance commands. Once the missile is active, the fighter capabilities no longer support the missile's mid-course (active) and end-game phases of the engagement sequence. The grayed-out capabilities are those systems that do not contribute to the particular segment of the engagement sequence. This mapping of fighter/missile capabilities to kill chain functions can be useful to both SEs and T&E practitioners in the development of test events or to perform system maturity assessments.
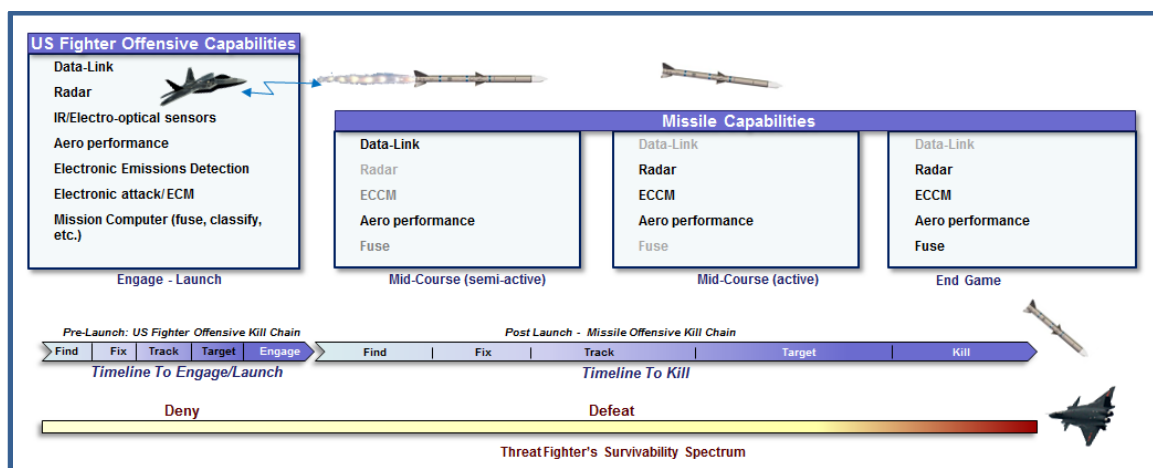

Figure 4. Notional US Fighter/Missile Capabilities Mapped across the Engagement Sequence

In order for the US fighter/missile engagement to be successful, it must "fight" through the threat fighter's defensive capabilities. These capabilities can also be aligned with the threat fighter's survivability spectrum that is intended to deny, defeat, and survive the US fighter's offensive engagement sequence (Figure 5). The grayed-out capabilities are those threat systems that do not contribute to defeating a particular segment of the engagement sequence.
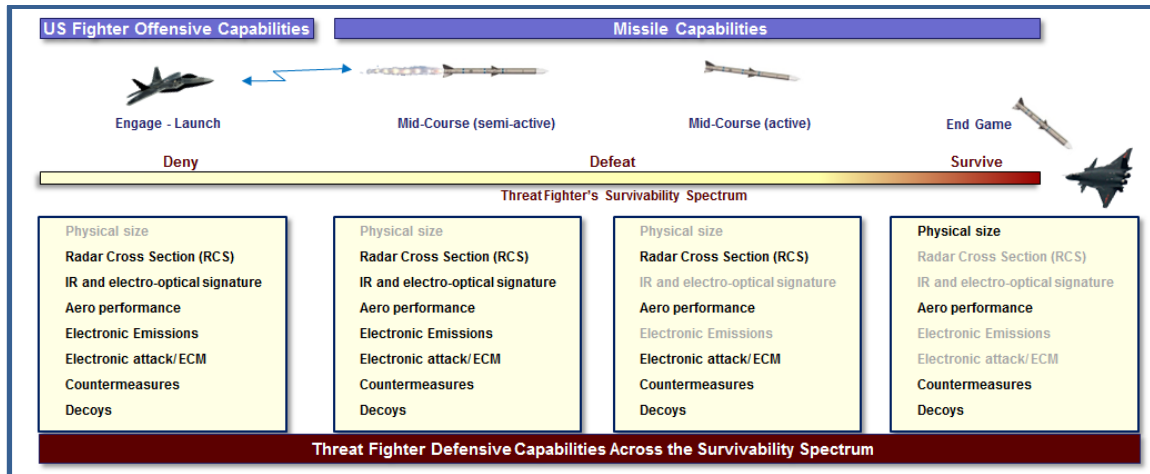
Figure 5. Notional Threat Fighter's Defensive Capabilities Mapped across the Engagement Sequence

Mission stream analysis can then present a composite of the engagement, which includes an alignment of US fighter/missile offensive capabilities intended to kill the threat with the threat fighter's defensive capabilities intended to deny/defeat/survive the engagement (Figure 6). This composite representation is useful when defining both US fighter and missile performance and effectiveness criteria for the developer and tester.
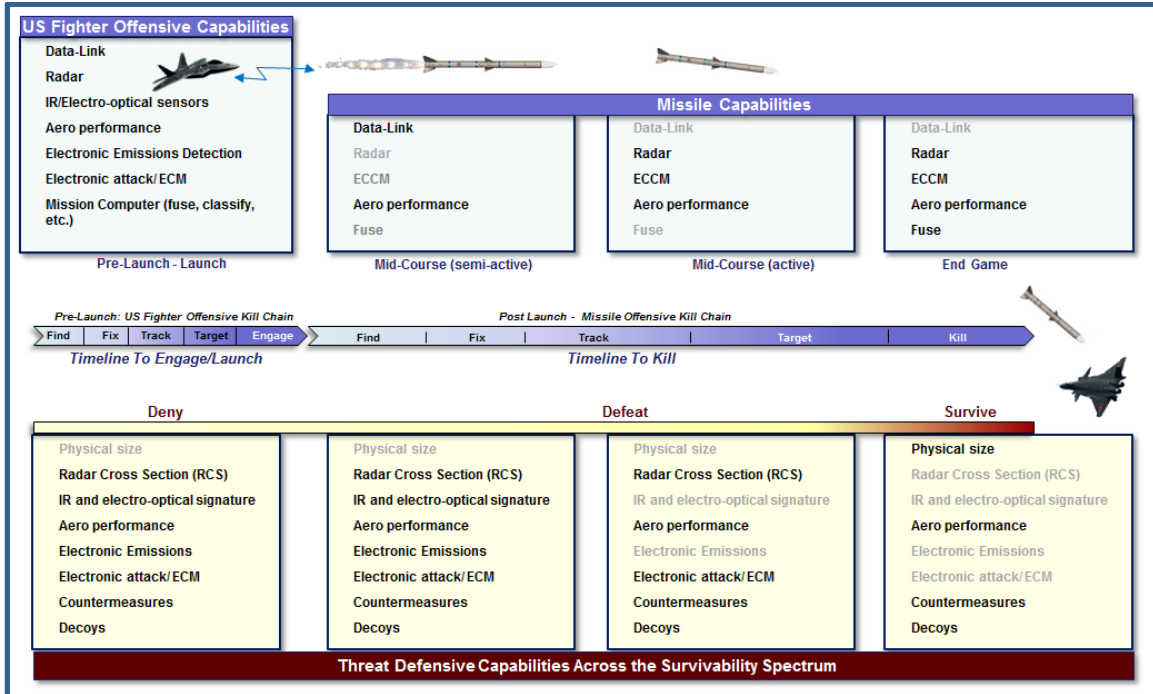

Figure 6. Notional Alignment of US Fighter/Missile Offensive Capabilities vs Threat Fighter's Defensive Capabilities Mapping

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From these relationships, the developers and testers can develop a relational template of the engagement sequence, such as the one shown in Figure 7. This template is populated with the threat-defensive capabilities that effect the sequencing and execution of the fighter's/missile's offensive kill chain; this may be useful with respect to test design or assessments. For example, if the developer and tester were concerned about a radar missile's active mid-course capabilities, they should focus the target configuration on replicating the threat defensive capabilities (e.g., radar cross section, aero performance, electronic attack, countermeasures, and decoys).

US Fighter/Missile Offensive Engagement Analysis	Fighter Pre-Launch Kill Chain vs Threat Fighter Defensive Capabilities					Post-Launch Missile Kill Chain vs Threat Fighter Defensive Capabilities				
	Find	Fix	Track	Target	Engage (Launch)	Find	Fix	Track	Target	Kill
Fighter - Pre-Launch	2-8	2-8	2-8	2-8	2-8					
Post Launch (Fighter - Data Link) – Missile semi-active								2-8	2-8	
Missile - active - Mid Course						2,4,6-8	2,4,6-8	2,4,6-8	2,4,6-8	
Missile - End Game Kill										1,4,7,8

Threat Fighter Defensive Capabilities that impact US Fighter/Missile offensive kill chains continuity include:
1. Physical size (desired for end-game fusing analysis)
2. Radar Cross Section (RCS)
3. IR and electro-optical signature
4. Aero performance (speed and maneuverability)
5. Electronic Emissions (e.g., IFF, Comm, etc.)
6. Electronic attack (includes Electronic Countermeasure (ECM) techniques which affect missile guidance and/or fusing)
7. Countermeasures
8. Decoys

Figure 7. Notional Mapping of Threat-Defensive Capabilities to Fighter/Missile Offensive Kill Chains

A similar analysis is conducted when the US fighter and the threat fighter's offensive and defensive roles are reversed; when the US fighter is under attack, it must employ its defensive capabilities across its survivability spectrum to deny, defeat, and survive the threat fighter/missile offensive kill chains.

A mission stream analysis template for reporting results of a US fighter/missile offensive missile engagement, with regard to the system's (fighter's) technical performance and pilot workload, is shown in Figure 8. Tests must be planned and executed specifically to collect this kind of data from a spectrum of data sources (e.g., hardware-in-the-loop facilities, systems integration laboratories, modeling and simulation, open air test ranges). The legend at the bottom of the figure provides the key

for interpreting the results presented. The system performance scale shows the objective and threshold values associated with the performance requirement, the best performance to date, and the performance demonstrated in this test scenario. The pilot workload scale provides the limits of unacceptable workload, little spare capacity, and insignificant workload; the values indicators are the same as the system performance scale. The color indicators on the system and pilot scales identify the test venue where the data were obtained. The test venues include such sources as test range, hardware-in-the-loop facility, and modeling and simulation.
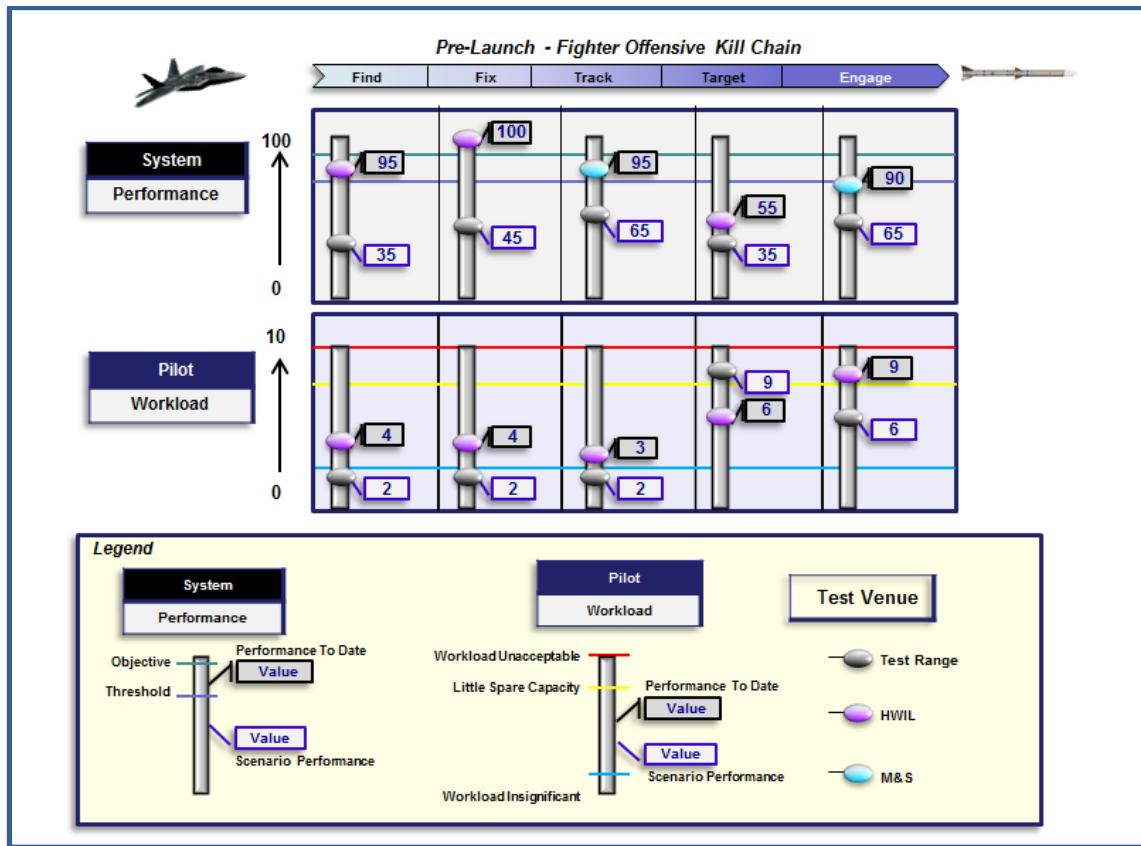

Figure 8. Mission Stream Analysis of System Technical Performance and Pilot Workload (Notional Pre-Launch Offensive Kill Chain (normalized))

Now, when reading the data, a large difference between the system's "scenario performances" and "performance to date" is an indication of the system's "excess capacity" or reserve capability; "scenario performance" reflects the end-to-end performance of each element of the system's kill chain for a specific scenario (i.e., requires successful completion of the kill chain for the engagement sequence); "performance to date" reflects a composite representation of the "best" performance of each element of the kill chain, independent of the scenario, seen to date (i.e., isolated performance of a kill chain element relative to its requirement (threshold and objective).

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In most cases, scenario testing does not stress the technical capabilities of the system, but it does inform on the robustness of the system, and provides an analytical basis for cost performance trades. For instance, under the kill chain fix function, the system performance indicates a 55 percent excess capacity for this scenario with acceptable pilot workload. However, under the targeting function, the system has not yet achieved its performance specifications and only 20 percent excess capacity was available in the test scenario; additionally, the pilot workload was high in the targeting function, indicating there may be human factor issues associated with the kill chain execution.

In conclusion, the benefits of a mission stream analysis are that it provides a mission-based presentation framework for senior leadership (e.g., Milestone Decision Authority (MDA), Program Executive Officer (PEO), Program Manager (PM), and warfighters) and a logical approach to structuring an efficient test program that emphasizes the collection of essential data to support key acquisition decisions. A mission stream analysis may assist senior leadership by providing mission context for cost performance trades, and for reporting test results and system maturity, specifically with regard to:

- Assessing test progress and current system performance against mission requirements

- Aligning program management priorities with mission requirements, particularly those relating to mission effectiveness, suitability, and survivability

- Providing a foundation for mission-based cost-performance trades and T&E planning and execution

Mission stream analysis, as a cross-domain tool, could enhance the foundational analysis of a program; aid in devolving the envisioned mission and system capability requirements into a system's technical performance and operator workload requirements; and help minimize the "delta" between domains across the systems lifecycle, from program definition through design, development, and test and evaluation, as described in the next section of the paper.

3. Role of Mission Stream Analysis in DoD Acquisition - Δ Analytic Model

A. The Acquisition Process

DoD Directive 5000.01[8] states: "The primary objective of Defense acquisition is to acquire quality products that satisfy user needs with measurable improvements to mission capability and operational support, in a timely manner, and at a fair and reasonable price." In essence, DoD develops weapon systems to <u>effectively</u> conduct <u>missions</u> and survive. The process normally begins with combatant commanders identifying mission needs and capability gaps/shortfalls. The process continues with the Joint Requirements Oversight Council (JROC) validating those mission needs; identifying a requirement for a material solution; and identifying the key performance parameters needed by a material solution to mitigate the gap. The focus is always on the mission. Once the requirement is validated, the acquisition process is focused on the development of a weapon system. An integral part of that development process is the verification and validation of its performance and the demonstration of its mission effectiveness. Ultimately it is the T&E professionals who must accurately summarize the system's and the operator's capabilities and limitations so that decision makers can reasonably judge the relationship of demonstrated system performance to the desired mission capability (effectiveness and suitability). These issues are not trivial.

The term "mission effectiveness" is defined as a measure of the overall ability of a weapon system to accomplish a mission when used by representative personnel in the operational employment of the system considering organization, doctrine, supportability, survivability, vulnerability, and threat.[9] In the context of mission stream analysis, it is the ability of the weapon system to successfully execute its offensive "kill chains" and survive the enemy's kill chain when conducting missions under operational conditions and in operationally relevant environments. Each mission set should have at least one defined measure of effectiveness (MOE) from which testable offensive and defensive performance attributes can be derived for the purpose of assessing mission accomplishment. Well-defined effectiveness measures are essential elements of a credible mission stream analysis.

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[8] DoDD 5000.01.

[9] *Manual for the Operation of the Joint Capabilities Integration and Development System*, January 31, 2011.

Mission stream analysis is an acquisition improvement tool that can help define requirements, identify systems and sub-systems that do not add value or contribute to the mission, and can help senior leadership better understand the mission capabilities of the system under development, particularly with respect to:

- Aligning program management priorities with achieving mission capabilities,

- Understanding the "so what" of test progress by assisting in relating system performance to mission effectiveness and suitability, and

- Providing a mission-based tool for cost-performance trades.

Establishing better cross-domain consensus with regard to missions, measures, and environments used to develop, validate, and demonstrate the system's capabilities to accomplish its mission would aid in improving the acquisition process. The focus should be on minimizing the differences, or "Δ", in defining missions, measures, and environments across domains. Acquisition professionals (engineers, testers, and resource analysts) have two immediate challenges early in the acquisition process: (1) establishing relevant MOEs that will provide insight into system performance and operator capabilities relative to mission requirements; and (2) defining the appropriate assessment activities necessary to evaluate the system's mission capabilities and limitations. However, developers and testers must prioritize their activities against schedule and resource constraints. These prioritization efforts must be undertaken within the context of delivering mission capability to the warfighter.

Historically, developers tend to focus on achieving specific performance specifications in isolation of human performance attributes and mission effectiveness and suitability objectives. As a result, programs can spend considerable resources to resolve shortfalls that have little impact on mission effectiveness. Conversely, developers can overlook the resolution of requirement shortfalls that are essential to warfighter needs. One example involves the F/A-18E/F Super Hornet integration of the Joint Stand Off Weapon (JSOW) C-1 variant that added a Link-16 datalink to the weapon. The development program proved to meet technical performance requirements, but excessive pilot workload associated with employing the weapon was not discovered until late in the development flight test program, as noted in CDR McFarland's presentation at the Society of Experimental Test Pilots 55th Annual Symposium. Below is an excerpt from the presentation abstract:[10]

> New capability is a quantum leap in warfighting solutions, but the flexibility comes at a cost. This cost is Aircrew Workload. Although there was a Simulation Design Advisory Group early on in the program, it was

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[10] LT Scott Johnson (USN) and CDR Andrew McFarland (USN), "Development Test of JSOW C-1 on the F/A-18E/F Super Hornet," Abstract (paper presented at the Society of Experimental Test Pilots 55th Annual Symposium, Anaheim, California, September 21–24, 2011).

unfortunately focused more on the functionality of NEW and less on human factors evaluation. This paper presents how human factors deficiencies have been identified throughout various stages of the test program, and the importance of identifying deficiencies and solutions as early as possible.

Mission stream analysis, if used during requirements development and system design, would have identified the importance of human performance in design earlier. That is, it would have provided better precision in defining missions, measures, and environments across domains with respect to human integration.

The Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System chart (Figure 9) outlines the key activities in the DoD systems acquisition process that must work in concert to deliver the capabilities required by the warfighters: the requirements process, the acquisition process, and the program and budget development process. These processes often create organizational confusion and stovepipes. For instance, a system's missions, measures, and environments, as envisioned by the warfighters, are validated by the JROC and documented in the Capabilities Development Document (CDD). However, they may be interpreted differently by the test community in their Test and Evaluation Master Plan (TEMP). The requirements and T&E communities do not share formal approval authority on these documents. As an example, Dr. Gilmore, Director, Operational Test and Evaluation (DOT&E), alluded to the organizational confusion and stovepipes in his September 13, 2013 memo, as excerpted below:[11]

- The fact that the P-8A can be fully compliant with KPP/KSA [Key Performance Parameter/Key System Attribute] thresholds while having significant shortfalls in mission effectiveness indicates that these "most essential" **operational requirements were focused too narrowly**. In this case, they define supporting system characteristics or attributes that are necessary, but not sufficient, to ensure mission effectiveness.

- The lack of KPPs/KSAs related directly to mission effectiveness will inevitably create a disconnect between the determination of operational effectiveness in test reports and the KPP/KSA compliance assessments that typically drive program reviews throughout development.

- Disconnects between KPP compliance assessments and operational testing that is focused on characterizing system effectiveness across the operational envelope are not unique to the P-8A program. Another example of this is the Class I Unmanned Aerial Vehicle (Class I UAV), the Tactical Unattended

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[11] "P-8A Poseidon Multi-mission Maritime Aircraft (MMA) Increment 1 Key Performance Parameters memo," Operational Test and Evaluation, September 4, 2013.

Ground Sensor (T-UGS) and the Urban Unattended Ground Sensor (UUGS) of the Army's Early Infantry Brigade Combat Team (E-IBCT) program. Those components of the E-IBCT program met all of the defined KPPs, but were not operationally effective since they provided little or no real operational value to the using unit in the intended operational environment.
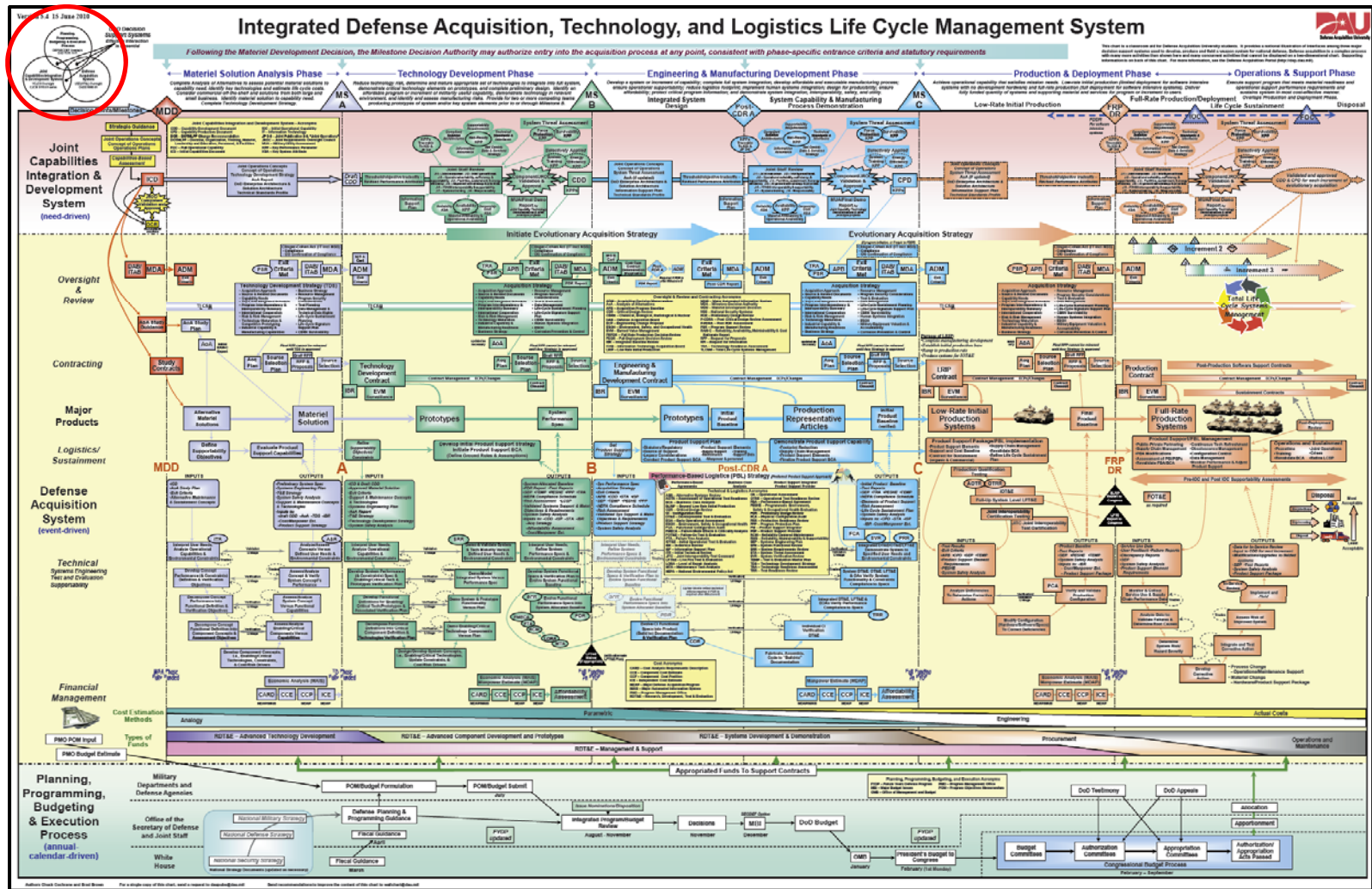
Source: Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System, Version 5.4, Defense Acquisition University (DAU), June 15, 2010.

Figure 9. Integrated Defense AT&L Life Cycle Management System

B. Developing the Δ Analytic Model

The Defense Acquisition Guidebook depicts a canonical Systems Engineering "V" Model (Figure 10), which reflects the DoD process used to develop weapon systems. The "V" Model assumes cross-domain collaboration through an "Integrated Product Team" process. Both the Integrated Defense Life Cycle Management System and the "V" Model are schedule- or timeline-centric when it comes to cross-domain collaboration. The various communities get involved when it is their "time" or when the process requires their involvement. Despite the time and effort invested in the DoD Systems Engineering Process, things still go wrong on programs, including misunderstanding of the requirements, inadequately defined technical baselines, erroneous programmatic and technical assumptions, inadequate developmental test programs, loss of corporate knowledge, legislative and program structure changes, etc.
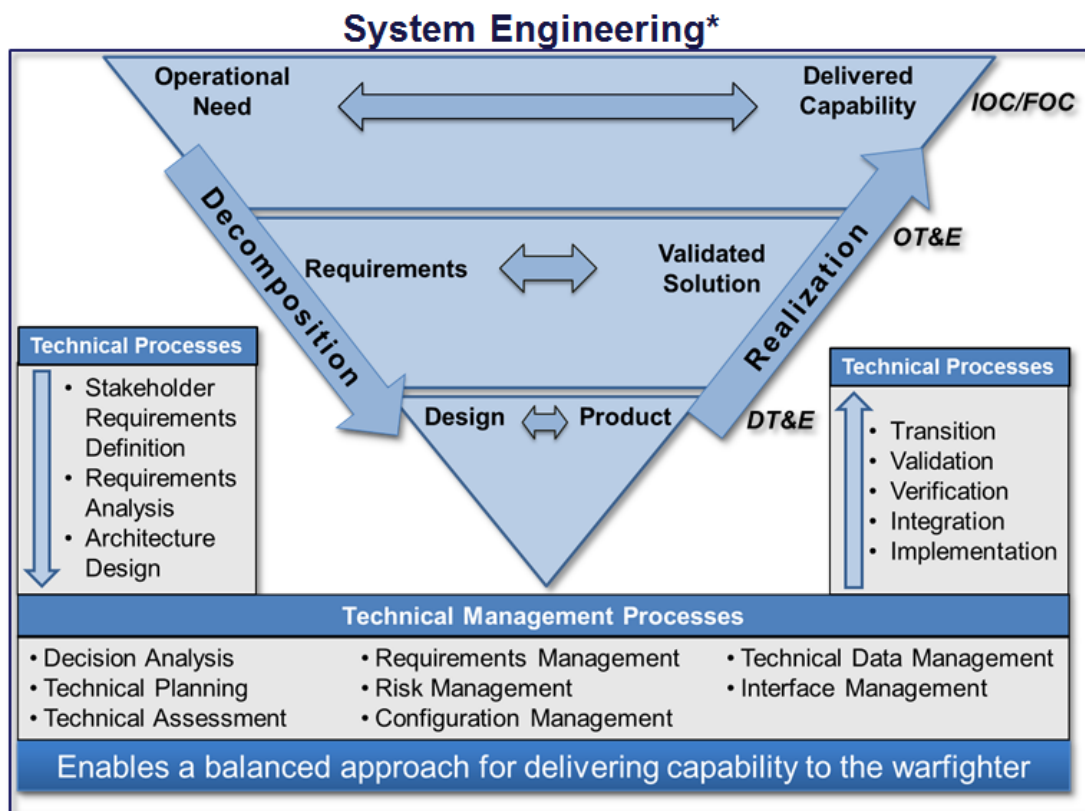
Figure 10. Systems Engineering "V" Model

It appears to us, that the "V" model lacks emphasis on the "mission" during requirements decomposition, which corrupts the integrity of the analytic foundation throughout the life cycle. Under these conditions, we see differences arise in domain-

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specific interpretations of the user's requirements. That is, the operational context (e.g., mission, kill chains, objectives, scenarios, measures) for which a weapon system's capability is defined (requirements) may be different from the context in which the system is designed (developer), which may also differ from the context used to validate the system's capability and limitations (test and evaluation). In one aircraft program, OT&E documented in the TEMP a planned evaluation for convoy and helicopter escort collateral missions, that was not in the Capabilities Production Document (CPD). For another aircraft program, the KPPs did not address any of the missions identified in the mission statement. A UAV program reported operational availabilities of 90 percent on systems that were fielded, but developmental tests were reporting failures and maintenance times that could not account for the 90 percent rating.

IDA proposes a Δ Analytic Model (Figure 11), which complements the "V" model. At the base of the Δ Analytic Model is the Analytic Foundation, which includes key elements of information needed by the communities of interest to execute their responsibilities. The term "delta" was selected to focus on eliminating the differences or "deltas" between communities, and between those common elements and assumptions relating to the system and its missions. In order to keep the differences like those cited above from developing, the Analytic Foundation must be transparent and readily available to all communities, and all communities must recognize the Analytic Foundation as the authoritative source of information. We envision a model that is not unlike Wikipedia with permissions.
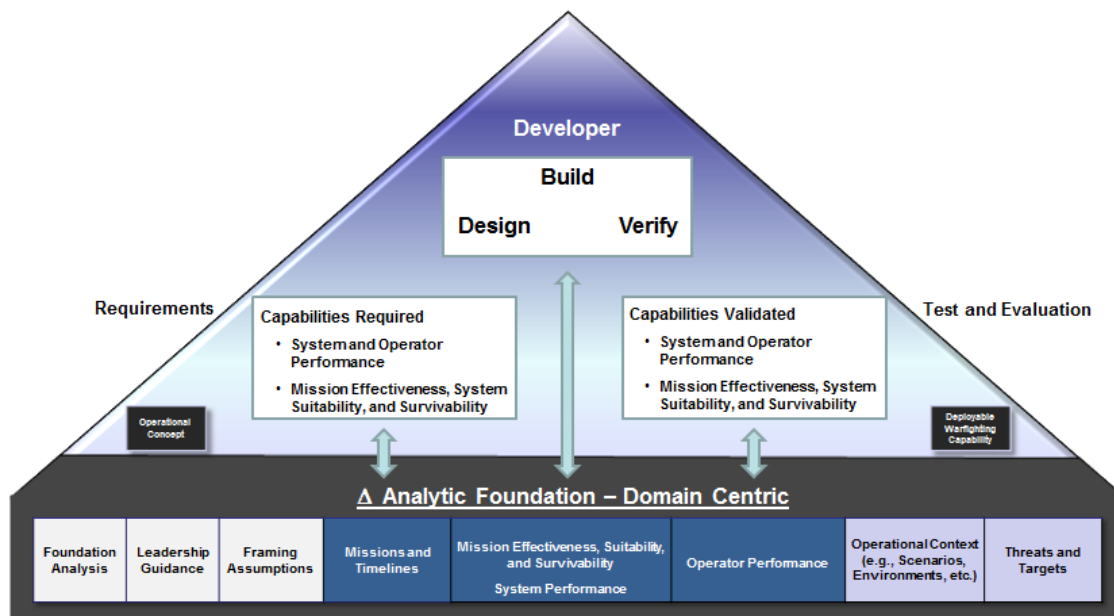

Figure 11. Δ Analytic Model

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The Δ Analytic Foundation elements include:

- Foundational Analysis (e.g., Capabilities-Based Assessment (CBA) and Gap Analysis)

- Leadership Guidance and Decisions

- Framing Assumptions

- Missions (definitions, objectives, kill chains, CONOPS, etc.)

- Mission Effectiveness, Suitability, and Survivability measures

- System Performance measures

- Operator Performance measures

- Operational Context (e.g., scenarios, mission tasks, kill chains, timelines, operating conditions and environment, and threats in which the system and operator are to perform each mission and each phase of a mission)

- Threats and Targets

- Others as required

Above the Analytic Foundation are all the decomposition and realization activities as described in the Systems Engineering "V" Model. The Δ Analytic Model is the "domain-centric" environment where communities reach <u>down</u> to the Analytic Foundation for key elements of information, regardless of the time phasing of the program; for instance, the operational context that was used in defining the requirements should be available for the developer and tester to help ensure that the same operational context is used to design and test the system.

Figure 12 depicts the cross-domain collaboration and synergy enabled by the "Δ" model throughout the life cycle. In this view of the model, the three communities (requirements, development, and test) are shown reaching into the Analytic Foundation to both retrieve and provide information.
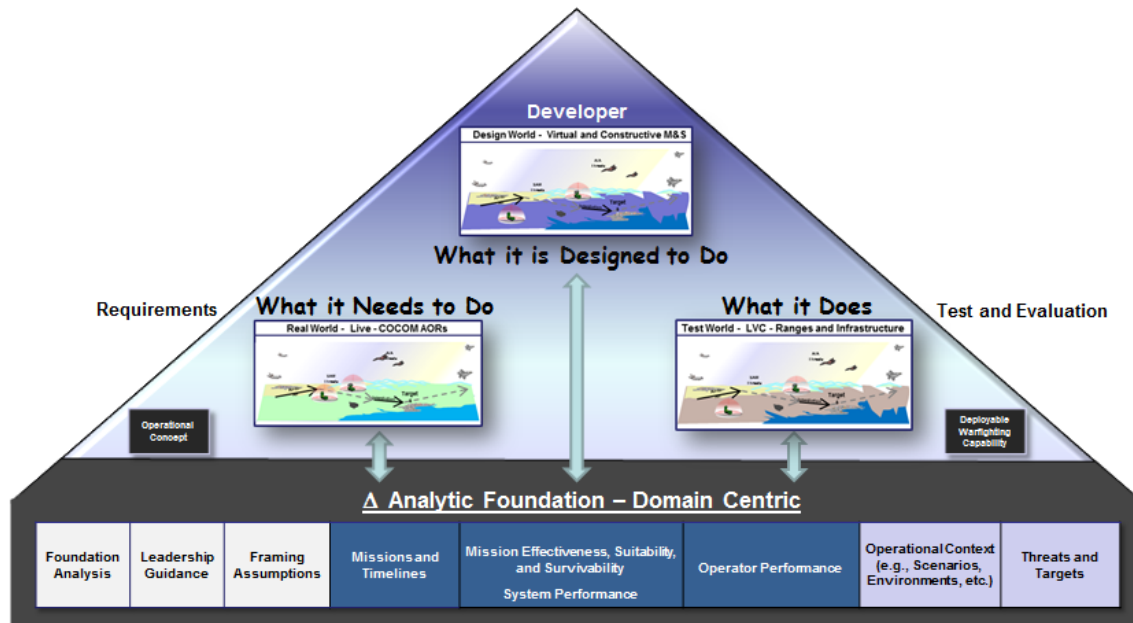
Figure 12. Cross-Domain Synergy

Key Δ Analytic Model domain responsibilities are described below:

- **Requirements (Real World)**: **What the System Needs to Do** – Provides the Foundational Analysis and Assumptions (e.g., CBA and Gap Analysis) and real world mission-focused requirements development. Mission set should have at least one MOE defined from which testable offensive and defensive performance attributes can be derived for the purpose of assessing mission accomplishment. System performance, suitability, and survivability attributes and operator capabilities should be defined with respect to the projected operational context (e.g., scenarios, threats, targets). The integrity of the operational context (including operational tasks, events, durations, frequency, operating conditions and environment, and capability requirements in which the system and operator are to perform each mission and each phase of a mission) should be maintained. Operational concepts and missions should be devolved into specific tasks (kill chains), technical performance attributes, and mission effectiveness measures:

  – Capability gap, affordability requirements, and need date

  – Mission-to-Task alignment and scenario-based task performance standards

  – Operational environments, scenarios, CONOPS, performance attributes, and MOEs

- **Development (Design World)**: **What the System is Designed to Do** – Enables system development in a mission-based context based on a better understanding of the real world and limitations of the design world. This will ensure that the "system" design is fully integrated with the "operator" in accomplishment of realistic end-to-end missions, and it aligns system and sub-system functions and performance attributes with the specified tasks (of the kill chain) in the mission context:

  – Provides the technical framework and analytic tools

  – Manages requirements, to include effectiveness, suitability, and performance measures

  – Identifies and mitigates development risk

- **Test and Evaluation (Test World)**: **What the System Does** – Validates the system's mission effectiveness, and system performance, suitability, and survivability capabilities and operator capabilities during T&E in the operational context for which the system was envisioned and designed. This provides an improved capability to quantify the differences between real world and test world limitations. It allows the evaluation, verification, and validation of system capabilities and limitations, ensuring that all required system performance and mission effectiveness requirements are planned and tested in the desired operational context (i.e., the ability to successfully execute weapon system "kill chains" when conducting missions under operationally relevant environments):

  – Balances risk within the T&E scope, schedule, and cost; develops the system T&E strategy and test plans

  – Associates KPPs with mission sets and the flowdown to test events

  – Identifies key resource constraints (e.g., targets, test infrastructure)

  – Highlights risks of proceeding with the test program in cases in which a weapon system is not yet meeting a system performance requirement or KPP

Figure 13 provides a template to document the understandings of each community. The analyst mines the existing documents for the documented domain-specific (rows) understanding of the products (columns) that contribute to a mission effective rating and enters the description into the template. Once filled in, the template provides evidence of the existence or absence of differences.

Figure 13. Minimizing the Δ across Domains

Figure 14 provides a specific example of the use of the template for a fighter program's "Offensive Counter Air" mission. We searched the Operational Requirements Document (ORD) for "need," the System Verification Plan (SVP) for "design," and the TEMP for "does."

Working down Column 2 for the Offensive Counter Air (OCA) mission, we found the ORD did not define operational context, in the SVP the contractor made up his own reference mission because reference missions were not provided for in the contract, and the TEMP cited the Joint Operational Test Team (JOTT)-defined missions.

Searching for MOEs and Performance (Column 3), we found that the ORD does not provide measures of effectiveness for any missions, the contractor derived his Critical Operational Issues (COIs) (and these were not required to track to the COIs in the TEMP), and the TEMP-defined MOEs track to JOTT-defined COIs based on test team rating.

Searching for Operator Performance (Column 4), we found that the ORD provided for the system to "Reduce Pilot Workload" without providing a comparative system, the designer assessed workload in a simulator, and OT&E depended on pilot ratings without providing a rating scale or thresholds to be met.

From this example, we can see that missions, effectiveness and performance criteria, and operator workload expectations differ greatly between communities.

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Δ Analytic Foundation – Domain Centric

Domain	FA	LG	FA	Missions	MOE and Performance	Operator Performance	OC	T/T
What it needs to do Requirements (Real World)				Offensive Counter Air – detailed mission objectives, CONOPS and operational context not provided in Operational Requirements Document (ORD)	Mission Effectiveness metrics not provided in ORD Performance measures limited to air vehicle performance; mission systems measures not provided in ORD	Reduce Pilot Workload – implies comparison; not stated. The ORD does not even provide a Qualitative rating scheme.		
What it is designed to do Developer (Design World)				Offensive Counter Air (OCA) - Due to the Performance Based nature of the contract, specific detailed reference missions were not provided by the government; contractor consolidated and established reference missions that aligned with contract	Contractor derived "Reference Mission Effectiveness requirements" discussed, but not criteria; technical performance measures (contract specs) track to a set of Critical Operational Issues (COI) and Contractor defined success criteria. Contractor defined COIs not required to track to COIs in TEMP COIs.	No Pilot work load metrics. Pilot systems/pilot interface (subjectivity) allocated to manned simulations; Pilot Vehicle Interface with complete avionics suite allocated to lab. Qualitative rating scheme not provided		
What it does T&E (Test World)				Offensive Counter Air - attributes OCA (airfield attack) cannot track to ORD or Contract DT&E will use Contractor defined reference missions; OT&E will use a Joint Operational Test Team (JOTT) defined missions which are different than DT&E	OT tester to evaluate mission effectiveness based on judgment; TEMP defined MOEs track to JOTT defined COIs based on test team rating. MOEs track to ORD but provide little value added from what is stated in the ORD.	Test venues for pilot workload not defined; Standard qualitative rating scale not defined.		

Figure 14. Notional Program that Highlights the Δ across Domains

The Δ Analytic Model is the "domain-centric" environment where communities reach <u>down</u> to the Analytic Foundation for key elements of information, regardless of the time phasing of the program; For the Δ Analytic Model to work, the Analytic Foundation must be transparent and readily available to all communities, and all communities must recognize the Analytic Foundation as the authoritative source of information. We envision a model that is not unlike Wikipedia with permissions. We believe adopting the model will improve cross-domain integration, communication, and analysis throughout the development lifecycle by:

- Focusing on the "real world" and maintaining the integrity of the analytic foundation

- Establishing the technical framework, and managing requirements around mission effectiveness, suitability, and survivability measures and the associated system performance attributes

- Codifying the system's Foundational Analysis and Assumptions, Leadership Guidance, and Framing Assumptions throughout the lifecycle

- Identifying and mitigating risk

4.   Summary

This paper describes two cross-domain analytic tools for enhancing the foundational analysis and the mission effectiveness outcome on major defense acquisition programs. The first tool is Mission Stream Analysis, which aids in decomposing the mission and system capabilities/requirements into system technical performance, operator workload requirements, and metrics that contribute to demonstrating mission effectiveness. The second tool is the Δ Analytic Model, which provides an approach for identifying disparate interpretations of the systems requirements and metrics in the analytic foundation so that the differences can be eliminated; i.e., the model helps minimize the difference (delta) in interpretations of requirements, performance parameters, and metrics by the various communities, specifically with regard to:

- What the system <u>needs</u> to do (requirements community)
- What it is <u>designed</u> to do (development community)
- What it <u>does</u> (T&E community)

Illustrations

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Abbreviations

AoA	Analysis of Alternatives
BDI	Bomb Damage Information
CBA	Capabilities Based Assessment
CDD	Capabilities Development Document
COMOPTEVFOR	Commander, Operational Test & Evaluation Force
COI	Critical Operational Issue
CONOPS	Concept of Operations
CPD	Capabilities Production Document
DAU	Defense Acquisition University
DoD	Department of Defense
DoDAF	DoD Architectural Framework
DOT&E	Director, Operational Test and Evaluation
ECM	Electronic Countermeasure
E-IBCT	Early Infantry Brigade Combat Team
IDA	Institute for Defense Analyses
IFF	Identification, Friend or Foe
IR	Infrared
JCIDS	Joint Capabilities Integration & Development System
JROC	Joint Requirements Oversight Council
JSOW	Joint Stand Off Weapon
KPP	Key Performance Parameter
KSA	Key System Attribute
MDA	Milestone Decision Authority
MMA	Multi-mission Aircraft
MOE	Measure of Effectiveness
MOP	Measure of Performance
OCA	Offensive Counter Air
ORD	Operational Requirements Document
OT&E	Operational Test and Evaluation
PEO	Program Executive Officer
PM	Program Manager
PPBE	Planning, Programming, Budgeting, and Execution
RCS	Radar Cross Section
RTB	Return to Base
SE	Systems Engineer

SVP	System Verification Plan
T&E	Test and Evaluation
TEMP	Test and Evaluation Master Plan
T-UGS	Tactical Unattended Ground Sensor
UAV	Unmanned Aerial Vehicle
US	United States
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology and Logistics
UUGS	Urban Unattended Ground Sensor

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14. ABSTRACT

Weapon system program development problems, as evidenced by significant cost increases and schedule delays, highlight the need to improve both the discipline of the development and test processes and the depth of analytic oversight provided for the Department of Defense (DoD) acquisition process. To address these needs, this paper provides two tools to supplement current DoD requirements development and test planning processes.

The "Δ Analytic Model" and companion "Mission Stream Analysis" are cross-domain analytic tools for enhancing the foundational analysis and the mission effectiveness outcome on major defense acquisition programs. The Δ Analytic Model provides an approach for identifying disparate interpretations of the systems requirements and metrics in the analytic foundation so that the differences can be eliminated; i.e., the model helps minimize the difference (delta) in interpretations of requirements, performance parameters, and metrics by the various communities (design, development, and test). Mission Stream Analysis aids in decomposing the mission and system capabilities/requirements into system technical performance, operator workload requirements, and metrics that contribute to demonstrating mission effectiveness.

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